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# WINTER AND SUMMER MEASUREMENTS OF EUROPEAN VERY LOW ALTITUDE VOLUME SCATTERING COEFFICIENTS

Richard W. Johnson

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The present report presents measurements of atmospheric volume scattering coefficients collected during winter and summer flights made during the Winter and Summer seasons of 1975 at two different European locations. The measurements were conducted during an instrumented aircraft high approach and landing as well as staging airbase. The measurements were made using a nephelometer with spectral response and thus are suitable for comparison with data associated with standard visibility determinations or airfield visibility.

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20 ABSTRACT continued

The data illustrate that in twenty-six of twenty-nine cases, there was little or no significant variation in the value of scattering coefficient as the aircraft approached the surface from an altitude of several hundred meters.

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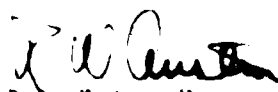
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**WINTER AND SUMMER MEASUREMENTS OF EUROPEAN  
VERY LOW ALTITUDE VOLUME SCATTERING COEFFICIENTS**

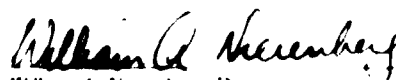
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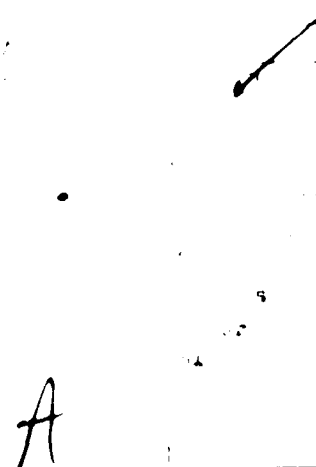
## SUMMARY

This report, which describes portions of the Visibility Laboratory's Project OPAQUE effort, was prepared under AFGL Contract F19628-78 C-0200. It contains a presentation of 29 low altitude scattering coefficient profiles and related meteorological data that were measured during the Winter and Summer seasons of 1978 at four different geographical locations. The measurements were conducted during an instrumented aircraft's approach and landing at four of the staging bases associated with the overall OPAQUE program. Johnson *et al.* (1979)

The nephelometer measurements of total volume scattering coefficient which are presented in this report were made using a pseudo-photopic spectral response having a mean wavelength of 557nm, and are thus suitable for comparison with data associated with standard visual determinations of airfield visibility. The temperature and dewpoint temperature measurements were made using an AN/AMQ-17 aerograph and a Cambridge Model 137-C3 Aircraft Hygrometer System. Measurements of horizon and terrain luminances which were also made during these aircraft descents are not included in this report, but are available in the Visibility Laboratory's basic data base should their subsequent analysis become desirable.

The reported data illustrate that in twenty-six out of twenty-nine cases, there was little or no significant variation in the photopic scattering coefficient as one approaches the surface from an altitude of several hundred meters. Thus modelling approximations of low altitude haze properties based upon near surface measurements are in general appropriate for the range of meteorological conditions extant during these flights.

A



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# WINTER AND SUMMER MEASUREMENTS OF EUROPEAN VERY LOW ALTITUDE VOLUME SCATTERING COEFFICIENTS

Richard W. Johnson

## 1. INTRODUCTION

In the increasingly sophisticated world of electro-optical detection, search, and guidance, the requirement for establishing and predicting atmospheric influences on system performance continues to develop as a primary operational necessity. It is in support of this general context that the Visibility Laboratory in cooperation with, and under the sponsorship of the Air Force Geophysics Laboratory has maintained an extensive program of airborne optical and meteorological measurements. In recent years this program has been conducted as an independent but cooperative effort [Johnson *et al.* (1979)] in conjunction with the NATO program OPAQUE (Optical Atmospheric Quantities in Europe), Fenn (1978). During the two year interval spanning the years 1977 and 1978, over 80 missions were flown documenting the vertical structure of the visible spectrum total volume scattering coefficient in the lower troposphere. Since a thorough awareness of this vertical structure is essential to the prediction of atmospheric influences on contrast transmittance through this regime, these data have been presented in a series of technical reports, the most recent of which is entitled "Airborne Measurements of Atmospheric Volume Scattering Coefficients in Northern Europe, Summer 1978", Johnson and Gordon (1980).

The optimum use of the experimental data presented in reports such as Johnson and Gordon (1980) is surely to establish the baseline assessment of those optical characteristics most influencing slant path contrast transmittance, and to develop from these assessments realistic predictive models. An initial effort in this model development, using both surface and profile data from the OPAQUE program is discussed in Johnson *et al.* (1979), and the further application of these data to contrast transmittance modelling is illustrated by Hering (1981).

A necessary but unfortunate artifact of the data presented in the report series referred to above, Johnson and Gordon (1980) etc. is that the measurements were always terminated at some significant altitude above

ground level. A necessary condition imposed by the safety of flight regulations which apply to a civil air space, and an unfortunate condition due to the extreme sensitivity of slant path contrast transmittances to variations in the near surface haze conditions. Thus, even though the structure of the atmospheric scattering coefficient profile has been well documented within the altitude regime between 6 km and about 1 km above ground level, the true character of the near surface layer has been relatively undetermined. Several methods of extrapolation from the lowest measured data value have been used to identify the most probable values of scattering coefficient within this region, as have intermittent instances of interpolation between airborne and surface measurements when both were available. Obviously, neither of these techniques addresses the determination of the shape of the profile within the first kilometer above the surface. Consequently, there exists a significant degree of uncertainty in how one should properly define this altitude regime when attempting to calculate or predict its optical properties. This uncertainty is particularly troublesome when one addresses operational scenarios involving low flying systems whose mission depends upon the adequate performance of its electro-optical devices.

The data contained in this report are intended to reduce, at least in part, the uncertainties in the structure of the near surface scattering coefficient profile. These data, identified in Table I.1, represent measurements made following each experimental data flight during the instrumented aircraft's approach and landing sequences. Thus the measurements were made in the specific region of interest, *i.e.* between the approach pattern altitude of approximately 1200 ft and the surface, and can be used directly to identify the optical characteristics of this tactically critical transition zone. The flights indicated in Table I.1 are all from the OPAQUE IV and V deployments, Johnson and Gordon 1979 and 1980, and thus represent only a sub-set of the total available data base. A second report, currently in preparation, will present similar data for the predominantly Spring and Fall time periods.

Table 1.1. Flight Identification Data

Aerodrome Identification	Flight No	Flight Date	Landing Time (GMT)
Sigonella, Sicily 37°24'N 14°55'E 24m MSL	432	03 Feb 78	150001
	433	17 Feb 78	130853
	434	18 Feb 78	140005
	460	02 Aug 78	154910
	461	03 Aug 78	124724
	462	05 Aug 78	132230
	463	07 Aug 78	134112
Wunstorf, Germany 52°28'N 09°25'E 57m MSL	451	22 Mar 78	144535
	452	23 Mar 78	160830
	454	28 Mar 78	141440
	456	31 Mar 78	161702
	465	14 Aug 78	153657
	466	15 Aug 78	134150
	468	21 Aug 78	131440
Memmingen, Germany 47°59'N 10°13'E 634m MSL	469	22 Aug 78	160952
	435	23 Feb 78	104356
	436	23 Feb 78	152402
	437	27 Feb 78	135823
	439	01 Mar 78	145643
	471	11 Sep 78	092904
	473	11 Sep 78	163609
Mildenhall, England 52°22'N 00°29'E 10m MSL	443	09 Mar 78	155711
	444	11 Mar 78	162448
	445	13 Mar 78	132659
	447	15 Mar 78	150413
	448	17 Mar 78	144958
	475	15 Sep 78	174646
	476	16 Sep 78	153834
	477	18 Sep 78	152524

Note: GMT times are indicated in Hours-Minutes-Seconds

## 2. PROCEDURES & INSTRUMENTATION

The general flight sequences conducted during the OPAQUE measurement program have been reported in several preceding reports as noted in bottom row entries of Table 2.1. In these earlier reports, measurements of atmospheric volume scattering coefficient and natural irradiance levels were presented for a broad variety of geographical and seasonal conditions. The general locale for these data missions is illustrated in Fig. 2-1 which has been abstracted from Johnson *et al.* (1979). The aerodromes at which the approach data were measured are indicated by the symbol, ★.

The instrumentation used during these flight episodes has been described adequately in the previously referenced reports [Johnson and Gordon (1980), etc.] and will not be further elaborated upon herein. Suffice it to say that the entire instrument system was mounted on an Air Force C-130 aircraft and included, but was not limited to, the following listed items:

- A multi-channel, multi-spectral nephelometer for the measurement of atmospheric total volume scattering coefficient and directional scattering functions,
- multi-spectral scanning radiometers for the measurement of sky and terrain radiances,
- a multi-spectral, two channel flat plate irradiator for the measurement of upwelling and downwelling irradiance levels, and
- meteorological transducers for the measurement of ambient temperature, dewpoint temperature and atmospheric pressure.

A special measurement sequence was associated with most flights discussed in these earlier reports, but its resultant data were not included as part of the standard flight package, nor included in those reports. These specialized data resulted from having the airborne optical, meteorological, and data logging instrumentation operational during the aircraft's landing approach and touchdown. Thus, since the aircraft was staging out of an airfield generally remote from the standard OPAQUE flight tracks shown in Fig. 2-1, two separate and independent data sets were collected during most missions. The

Table 2.1. Geographical and Seasonal Distribution of Low Altitude Scattering Coefficient Profiles

Aerodrome Locations (see Fig. 2.1)	Attempted Low Altitude Data Sequences					Totals
	Spring, 1976	Fall, 1976	Summer 1977 & 1978	Winter 1978		
Sigonella, Sicily	0	0	4*	4*		8
Toulon, France	0	4	1	0		5
Memmingen, Germany	0	0	6*	6*		12
Wunstorf, Germany	3	5	13*	4*		25
Snoeterberg, Netherlands	1	0	0	0		1
Mildenhall, England	4	0	1*	6*		11
Laerlose, Denmark	2	1	4	0		7
Totals	10	10	30	20		70
Related Data Reports	AFGL TR 77-0078	AFGL TR 77-0219	AFGL TR 78-0168 AFGL TR 80-0207	AFGL TR 79-0159	AFGL TR 79-0228	

\* Asterisk indicates those sub-sets from which the data in this report were chosen

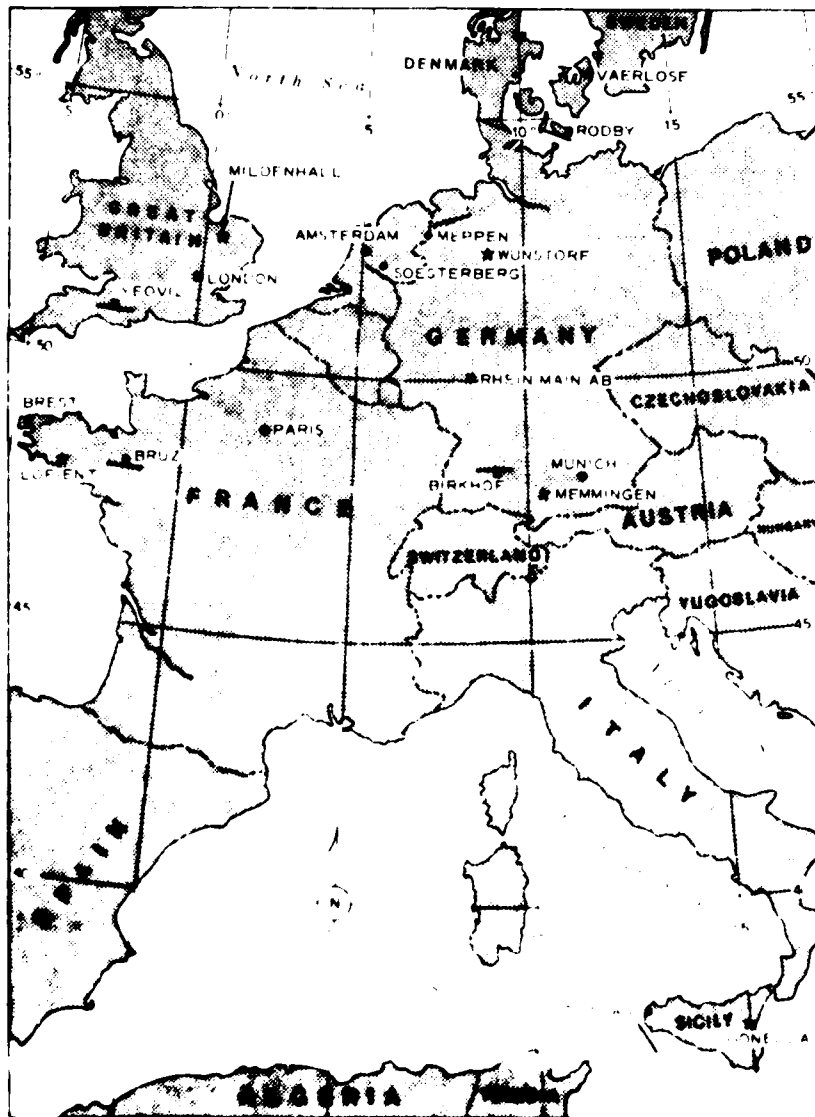


Fig. 1. Typical OPAQUE High Tracks

first was the rather extensive multi-spectral set of measurements made along the indicated tracks between 6 and 10 kilometers in altitude, and the second was the smaller more selective set made at the local staging base between about 6.7 and 9.0 kilometers. This second set of measurements, made only in the photopic spectral band, is nominally referred to as the APPROACH data.

There were several special considerations imposed during the collection of the APPROACH measurements which distinguish these data from the larger set previously reported. In general, they were as follows:

Measurements were made in only one spectral band. During the APPROACH descent from approximately 1200 ft AGL to the surface, the structural character of the scattering coefficient profile was the datum most desired. Thus the integrating nephelometer was pre-set to make continuous measurements of the photopic ( $\lambda = 557\text{nm}$ ) total scattering coefficient throughout the descent. By not switching optical filters, all measurements were accomplished with the optimum spatial resolution.

Measurements were made with pre-set, static optical configurations. This consideration was also imposed

to eliminate unnecessary time sharing sequences and thus optimize the detection of profile variations during the relatively short descent episodes. Thus the nephelometer was pre-set to measure total scattering coefficient only without cycling through the directional channels; the scanning radiometers were pre-set to stare at the sky and terrain directly ahead of the aircraft, approximately 5° above and 5° below the local horizon; and the dual channel irradiator was pre-set to measure total downwelling irradiance throughout the descent.

3. Data logging began shortly before the initiation of the aircraft's final descent for landing and continued throughout the descent and actual aircraft touchdown on the runway. Some editing has been required to eliminate spurious pre-descent and post-landing data which were adversely influenced by abnormal aircraft attitudes during initial line up and prop reversal influences during roll-out.

Post deployment data processing of these data has been handled in a manner similar to that described in Johnson and Gordon (1979). Calibration data for each deployment set is the same as was used for the parent data sets as referenced in each of the Related Data Report entries of Table 2.1. Readers are referred to these more detailed reports for supplementary background information where required.

### 3. WEATHER SUMMARY

The weather conditions existing during each of the flight episodes from which the APPROACH profiles have been extracted are discussed in detail in Johnson and Gordon (1979 and 1980). These parent reports include data from daily surface and 500 millibar charts, surface observations, pilot reports, vertical cross sections and radiosonde launches. The bulk of these data were provided by the U.S. Air Force Environmental Technical Applications Center (USAF/ETAC) at Scott Air Force Base, and the National Oceanographic and Atmospheric Administration via the National Climatic Center in Asheville, North Carolina.

Comparisons between the C-130 and RAOB airborne measurements of temperature, dewpoint temperature, and the derived values of relative humidity for each of the winter and summer flights preceding these APPROACH episodes have been made in the parent reports referenced above. However, several additional comparisons are summarized herein which relate more directly to the actual landing circumstances.

Measured values of temperature (t), dewpoint temperature (dp), and atmospheric pressure (p), that were recorded at the exact moment of landing touchdown have been compared with the equivalent values reported by the host aerodrome for eighteen of the flights reported in Sec-

tion 4. These flights were those for which the flight dynamics data permitted a specific and unambiguous determination of the exact instant of landing. Those flights for which the landing time was for any reason not specific were not included in the comparison, even though their data might in fact be suitable in all other respects. These comparisons are listed in Table 3.1. In all cases the differences,  $\Delta t$ ,  $\Delta dp$  and  $\Delta p$ , represent the aerodrome measurement minus the C-130 measurement.

The data summarized in Table 3.1 indicate that the airborne and aerodrome measurements were, on the average, in reasonable agreement. The temperature differences indicate a systematic difference of about 1.0 degree between C-130 and aerodrome measurements, however, the dewpoint and pressure measurements indicate no such systematic offset.

**Table 3.1** Comparison of Aerodrome & C-130 Data (All Measurements During Landing)

Aerodrome	Flight Number	Temperature $\Delta t$ (°C)	Dew Point $\Delta dp$ (°C)	Pressure $\Delta p$ (mb)
Sigonella	432	+1.9	0	
	433	+0.2	+1.7	
	461	+2.2	+4.4	0
	463	+0.6	+2.7	
Wunstorf	451	+0.6	+4.4	0
	454	+4.0	0	
	468	+0.2	0	
	469	+0.0	2.5	
Memmingen	435	+0.2	0	+4
	436	+0.3	0	0
	437	+0.0	0	0
	470	+0.9	+0.9	0
Mildenhall	440	+0.4	+0.8	
	444	+0.0	0	0
	445	+0.9	0	
	475	+0.0	+0.7	
	476	+0.0	0	0
	477	+0.2	0.4	
Overall Average	18 Flights	+0.7	+1.0	0

**Note:**

1.  $\Delta t$  is positive for all 18 flights in part, systematic bias in low measurement by the C-130 system.

2.  $\Delta dp$  &  $\Delta p$  reflect both positive and negative values interspersed throughout the 18 flights.

Since the staging aerodromes for most of these flights were generally remote from the primary data tracks, selected supplemental weather data related specifically to the APPROACH site have been included herein. Short summaries of the meteorological observations taken at the staging aerodrome, at or near the time of landing, are presented in Table 3.2. A glossary of the most often used symbols is included in Appendix A for the reader's convenience. All data were reported in Greenwich Civil Time (GCT), which is equivalent to Greenwich Mean Time (GMT), the terminology used in Table 3.2.

Table 1 is a vignette, with standard Metropolitan Data Sheet (see Table 4) and a list of 10 items.

		Weather and Sea State		Wind	Current	Time	Remarks
No.	Lat. Long.	Direction & Force	State of Sky	Direction & Force	Direction & Force	Time	Remarks
Page No. 400	Lat. 38° 00' N. Long. 120° 00' W.						
01	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
02	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
03	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
Day 100 Weathering - Strong wind from the N. E. during the afternoon							
Page No. 401	Lat. 38° 00' N. Long. 120° 00' W.						
04	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
05	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
Page No. 402	Lat. 38° 00' N. Long. 120° 00' W.						
06	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
07	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
Day 100 Weathering - Strong wind from the N. E. during the afternoon							
Page No. 403	Lat. 38° 00' N. Long. 120° 00' W.						
08	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
09	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
10	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
Day 100 Weathering - Strong wind from the N. E. during the afternoon							
Page No. 404	Lat. 38° 00' N. Long. 120° 00' W.						
11	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
12	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
13	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
Day 100 Weathering - Strong wind from the N. E. during the afternoon							
Page No. 405	Lat. 38° 00' N. Long. 120° 00' W.						
14	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
15	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
16	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
Day 100 Weathering - Strong wind from the N. E. during the afternoon							
Page No. 406	Lat. 38° 00' N. Long. 120° 00' W.						
17	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
18	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
19	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
Day 100 Weathering - Strong wind from the N. E. during the afternoon							
Page No. 407	Lat. 38° 00' N. Long. 120° 00' W.						
20	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
21	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
22	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
Day 100 Weathering - Strong wind from the N. E. during the afternoon							
Page No. 408	Lat. 38° 00' N. Long. 120° 00' W.						
23	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
24	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
25	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
Day 100 Weathering - Strong wind from the N. E. during the afternoon							
Page No. 409	Lat. 38° 00' N. Long. 120° 00' W.						
26	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
27	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
28	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
Day 100 Weathering - Strong wind from the N. E. during the afternoon							
Page No. 410	Lat. 38° 00' N. Long. 120° 00' W.						
29	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
30	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
31	Lat. 38° 00' N. Long. 120° 00' W.						Strong wind
Day 100 Weathering - Strong wind from the N. E. during the afternoon							

Table 1.2b. *Versammlungen (German)* Standard Meeting (English) (continued)

Summary - 1978									
Time	Flight No.	Date	Time	Altitude	Speed	Direction	Remarks	Remarks	Remarks
10:00	101	10/10/78	10:00	1000	100	100	100	100	100
10:05	102	10/10/78	10:05	1000	100	100	100	100	100
10:10	103	10/10/78	10:10	1000	100	100	100	100	100
10:15	104	10/10/78	10:15	1000	100	100	100	100	100
10:20	105	10/10/78	10:20	1000	100	100	100	100	100
10:25	106	10/10/78	10:25	1000	100	100	100	100	100
10:30	107	10/10/78	10:30	1000	100	100	100	100	100
10:35	108	10/10/78	10:35	1000	100	100	100	100	100
10:40	109	10/10/78	10:40	1000	100	100	100	100	100
10:45	110	10/10/78	10:45	1000	100	100	100	100	100
10:50	111	10/10/78	10:50	1000	100	100	100	100	100
10:55	112	10/10/78	10:55	1000	100	100	100	100	100
11:00	113	10/10/78	11:00	1000	100	100	100	100	100
11:05	114	10/10/78	11:05	1000	100	100	100	100	100
11:10	115	10/10/78	11:10	1000	100	100	100	100	100
11:15	116	10/10/78	11:15	1000	100	100	100	100	100
11:20	117	10/10/78	11:20	1000	100	100	100	100	100
11:25	118	10/10/78	11:25	1000	100	100	100	100	100
11:30	119	10/10/78	11:30	1000	100	100	100	100	100
11:35	120	10/10/78	11:35	1000	100	100	100	100	100
11:40	121	10/10/78	11:40	1000	100	100	100	100	100
11:45	122	10/10/78	11:45	1000	100	100	100	100	100
11:50	123	10/10/78	11:50	1000	100	100	100	100	100
11:55	124	10/10/78	11:55	1000	100	100	100	100	100
12:00	125	10/10/78	12:00	1000	100	100	100	100	100
12:05	126	10/10/78	12:05	1000	100	100	100	100	100
12:10	127	10/10/78	12:10	1000	100	100	100	100	100
12:15	128	10/10/78	12:15	1000	100	100	100	100	100
12:20	129	10/10/78	12:20	1000	100	100	100	100	100
12:25	130	10/10/78	12:25	1000	100	100	100	100	100
12:30	131	10/10/78	12:30	1000	100	100	100	100	100
12:35	132	10/10/78	12:35	1000	100	100	100	100	100
12:40	133	10/10/78	12:40	1000	100	100	100	100	100
12:45	134	10/10/78	12:45	1000	100	100	100	100	100
12:50	135	10/10/78	12:50	1000	100	100	100	100	100
12:55	136	10/10/78	12:55	1000	100	100	100	100	100
13:00	137	10/10/78	13:00	1000	100	100	100	100	100
13:05	138	10/10/78	13:05	1000	100	100	100	100	100
13:10	139	10/10/78	13:10	1000	100	100	100	100	100
13:15	140	10/10/78	13:15	1000	100	100	100	100	100
13:20	141	10/10/78	13:20	1000	100	100	100	100	100
13:25	142	10/10/78	13:25	1000	100	100	100	100	100
13:30	143	10/10/78	13:30	1000	100	100	100	100	100
13:35	144	10/10/78	13:35	1000	100	100	100	100	100
13:40	145	10/10/78	13:40	1000	100	100	100	100	100
13:45	146	10/10/78	13:45	1000	100	100	100	100	100
13:50	147	10/10/78	13:50	1000	100	100	100	100	100
13:55	148	10/10/78	13:55	1000	100	100	100	100	100
14:00	149	10/10/78	14:00	1000	100	100	100	100	100
14:05	150	10/10/78	14:05	1000	100	100	100	100	100
14:10	151	10/10/78	14:10	1000	100	100	100	100	100
14:15	152	10/10/78	14:15	1000	100	100	100	100	100
14:20	153	10/10/78	14:20	1000	100	100	100	100	100
14:25	154	10/10/78	14:25	1000	100	100	100	100	100
14:30	155	10/10/78	14:30	1000	100	100	100	100	100
14:35	156	10/10/78	14:35	1000	100	100	100	100	100
14:40	157	10/10/78	14:40	1000	100	100	100	100	100
14:45	158	10/10/78	14:45	1000	100	100	100	100	100
14:50	159	10/10/78	14:50	1000	100	100	100	100	100
14:55	160	10/10/78	14:55	1000	100	100	100	100	100
15:00	161	10/10/78	15:00	1000	100	100	100	100	100
15:05	162	10/10/78	15:05	1000	100	100	100	100	100
15:10	163	10/10/78	15:10	1000	100	100	100	100	100
15:15	164	10/10/78	15:15	1000	100	100	100	100	100
15:20	165	10/10/78	15:20	1000	100	100	100	100	100
15:25	166	10/10/78	15:25	1000	100	100	100	100	100
15:30	167	10/10/78	15:30	1000	100	100	100	100	100
15:35	168	10/10/78	15:35	1000	100	100	100	100	100
15:40	169	10/10/78	15:40	1000	100	100	100	100	100
15:45	170	10/10/78	15:45	1000	100	100	100	100	100
15:50	171	10/10/78	15:50	1000	100	100	100	100	100
15:55	172	10/10/78	15:55	1000	100	100	100	100	100
16:00	173	10/10/78	16:00	1000	100	100	100	100	100
16:05	174	10/10/78	16:05	1000	100	100	100	100	100
16:10	175	10/10/78	16:10	1000	100	100	100	100	100
16:15	176	10/10/78	16:15	1000	100	100	100	100	100
16:20	177	10/10/78	16:20	1000	100	100	100	100	100
16:25	178	10/10/78	16:25	1000	100	100	100	100	100
16:30	179	10/10/78	16:30	1000	100	100	100	100	100
16:35	180	10/10/78	16:35	1000	100	100	100	100	100
16:40	181	10/10/78	16:40	1000	100	100	100	100	100
16:45	182	10/10/78	16:45	1000	100	100	100	100	100
16:50	183	10/10/78	16:50	1000	100	100	100	100	100
16:55	184	10/10/78	16:55	1000	100	100	100	100	100
17:00	185	10/10/78	17:00	1000	100	100	100	100	100
17:05	186	10/10/78	17:05	1000	100	100	100	100	100
17:10	187	10/10/78	17:10	1000	100	100	100	100	100
17:15	188	10/10/78	17:15	1000	100	100	100	100	100
17:20	189	10/10/78	17:20	1000	100	100	100	100	100
17:25	190	10/10/78	17:25	1000	100	100	100	100	100
17:30	191	10/10/78	17:30	1000	100	100	100	100	100
17:35	192	10/10/78	17:35	1000	100	100	100	100	100
17:40	193	10/10/78	17:40	1000	100	100	100	100	100
17:45	194	10/10/78	17:45	1000	100	100	100	100	100
17:50	195	10/10/78	17:50	1000	100	100	100	100	100
17:55	196	10/10/78	17:55	1000	100	100	100	100	100
18:00	197	10/10/78	18:00	1000	100	100	100	100	100
18:05	198	10/10/78	18:05	1000	100	100	100	100	100
18:10	199	10/10/78	18:10	1000	100	100	100	100	100
18:15	200	10/10/78	18:15	1000	100	100	100	100	100
18:20	201	10/10/78	18:20	1000	100	100	100	100	100
18:25	202	10/10/78	18:25	1000	100	100	100	100	100
18:30	203	10/10/78	18:30	1000	100	100	100	100	100
18:35	204	10/10/78	18:35	1000	100	100	100	100	100
18:40	205	10/10/78	18:40	1000	100	100	100	100	100
18:45	206	10/10/78	18:45	1000	100	100	100	100	100
18:50	207	10/10/78	18:50	1000	100	100	100	100	100
18:55	208	10/10/78	18:55	1000	100	100	100	100	100
19:00	209	10/10/78	19:00	1000	100	100	100	100	100
19:05	210	10/10/78	19:05	1000	100	100	100	100	100
19:10	211	10/10/78	19:10	1000	100	100	100	100	100
19:15	212	10/10/78	19:15	1000	100	100	100	100	100
19:20	213	10/10/78	19:20	1000	100	100	100	100	100
19:25	214	10/10/78	19:25	1000	100	100	100	100	100
19:30	215	10/10/78	19:30	1000	100	100	100	100	100
19:35	216	10/10/78	19:35	1000	100	100	100	100	100
19:40	217	10/10/78	19:40	1000	100	100	100	100	100
19:45	218	10/10/78	19:45	1000	100	100	100	100	100
19:50	219	10/10/78	19:50	1000	100	100	100	100	100
19:55	220	10/10/78	19:55	1000	100	100	100	100	100
20:00	221	10/10/78	20:00	1000	100	100	100	100	100
20:05	222	10/10/78	20:05	1000	100	100	100	100	100
20:10	223	10/10/78	20:10	1000	100	100	100	100	100
20:15	224	10/10/78	20:15	1000	100	100	100	100	100
20:20	225	10/10/78	20:20	1000	100	100	100	100	100
20:25	226	10/10/78	20:25	1000	100	100	100	100	100
20:30	227	10/10/78	20:30	1000	100	100	100	100	100
20:35	228	10/10/78	20:35	1000	100	100	100	100	100
20:40	229	10/10/78	20:40	1000	100	100	100	100	100
20:45	230	10/10/78	20:45	1000	100	100	100	100	100
20:50	231	10/10/78	20:50	1000	100	100	100		

Table 1.2: Weathered, Low-Grade Standard Meteorological Data Sheet (Lat 32°30'N, Long 97°30'W, Elev. 57m)

Station: 070

Time	Location	Station	Weather and Observations To Name	Temp °C	Humidity %	Pressure hPa	Wind m/s	Remarks
0000	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0100	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0200	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0300	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0400	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0500	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0600	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0700	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0800	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0900	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000

Station: 070

1000	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1100	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1200	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1300	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1400	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1500	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1600	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1700	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1800	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1900	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000

Table 1.3: Weathered, Low-Grade Standard Meteorological Data Sheet (Lat 32°30'N, Long 97°30'W, Elev. 57m)

Station: 070

Time	Location	Station	Weather and Observations To Name	Temp °C	Humidity %	Pressure hPa	Wind m/s	Remarks
0000	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0100	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0200	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0300	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0400	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0500	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0600	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0700	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0800	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
0900	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000

Station: 070

1000	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1100	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1200	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1300	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1400	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1500	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1600	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1700	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1800	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000
1900	1000	1000	1000	10.0	10.0	10.0	10.0	1000 1000

## 4. DATA PRESENTATION

### 4.1 Data and Flight Summary

During the summer of 1978, 2 Aug through 26 Sep, twenty flights were made in northern Europe, of which nineteen contained weather profile data. These data were reported in Johnson and Lunden (1981). The nineteen flights contained observable approach profiles. These thirteen flights are listed in Table 1.

During the preceding winter of 1978, 1980, thirty-eight flights were made in the same European regions, of which twenty-six contained observable data. These data were reported in Johnson and Lunden (1979). If these were not, they contained observable approach profiles which are listed with the approach and departure profiles.

### 4.2 Description of Data Tables and Graphs

The flight data in the APPENDIX H summarizes observations of the observed and predicted ground level wind, temperature, and summer measurements of wind and temperature, as well as other weather data.

The following tables in this section measure the wind and temperature during the flight, which are the wind and temperature data. The wind and temperature data are presented in the following tables. The wind and temperature data are presented in the following tables.

### 4.3 Supplementary Data Tables

The following tables in this section have been added to the APPENDIX H. The following tables have been added to the APPENDIX H.

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The following tables in this section have been added to the APPENDIX H. The following tables have been added to the APPENDIX H.



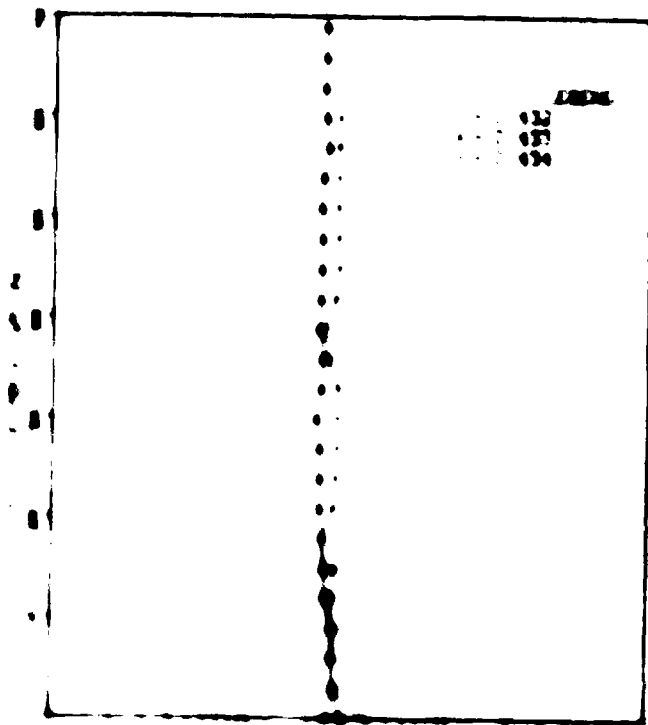
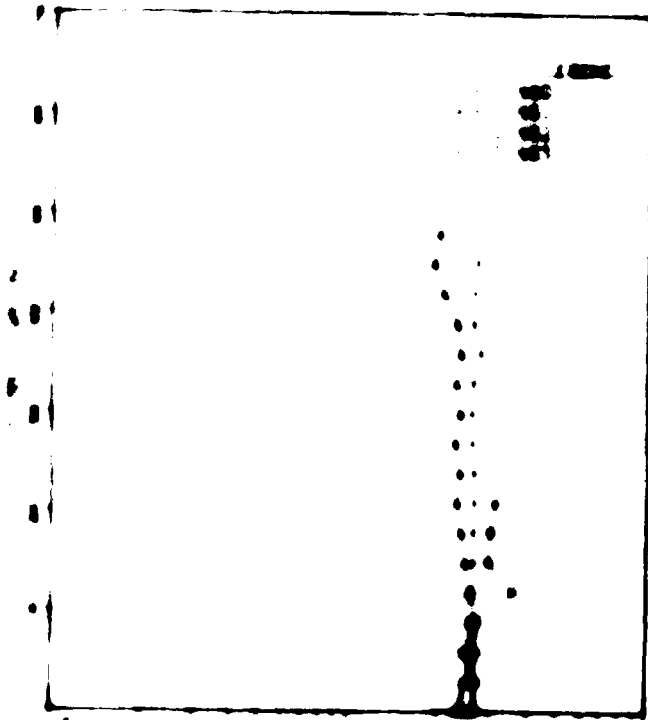


Fig. 1  
APPENDIX B PROFILE GRAPH A1

Vertical Scale  
Horizontal Scale



Vertical Scale  
Horizontal Scale

APPENDIX H FIFTH JS TABULAR

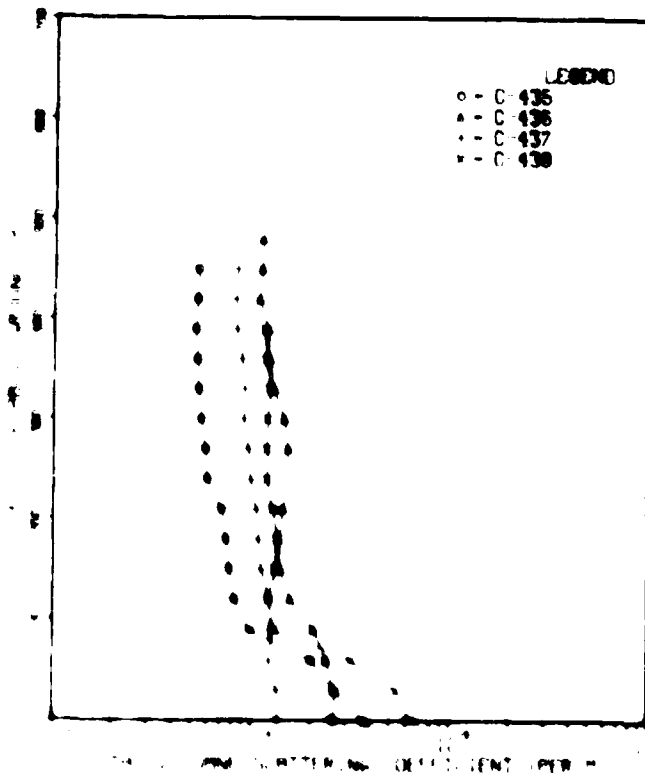
~~SECRET~~ ~~FOUO~~

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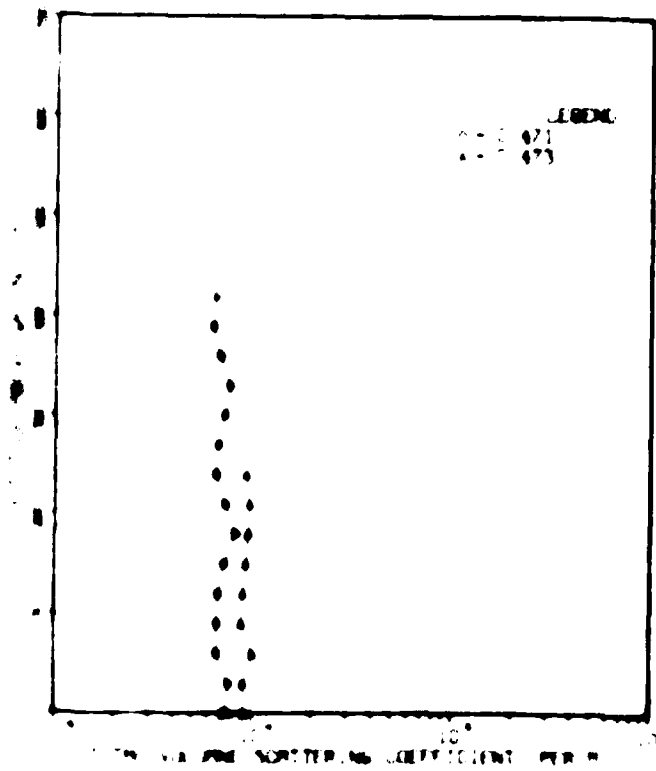
~~SECRET~~ 1070

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## APPROACH PROFILES - GRAPHICAL



**Münzingen, Germany**  
**Winter 1978**



Stammungen. (German)  
Summer 1978

Table 4.2

## APPROACH PROFILES - TABULAR

Münsterlingen, Germany

Winter 1978

Altitude (m) AGL	Total Volume Scattering Coefficient (m <sup>-1</sup> )			
	(.415)	(.436)	(.457)	(.479)
400		1100 .04		
450	5.274E-05	1000 .04	8.281E-05	
500	5.299E-05	1000 .04	8.227E-05	
550	5.100E-05	1197E-04	8.321E-05	1.147E-04
600	5.279E-05	1.215E-04	8.063E-05	1.099E-04
650	5.490E-05	2.077E-04	9.167E-05	1.227E-04
700	5.566E-05	1.850E-04	9.077E-05	1.192E-04
750	5.883E-05	1.516E-04	9.570E-05	1.100E-04
800	5.690E-05	1.476E-04	9.042E-05	1.106E-04
850	5.690E-05	1.400E-04	9.040E-05	1.275E-04
900	5.661E-05	1.460E-04	9.081E-05	1.190E-04
950	5.721E-05	1.400E-04	1.16E-04	1.100E-04
1000	5.761E-05	1.502E-04	1.290E-04	1.210E-04
90	9.817E-07	2.000E-04	1.261E-04	1.290E-04
80	2.000E-04	2.011E-04	2.120E-04	1.231E-04
70	1.671E-04	2.613E-04	1.51E-04	5.413E-04
60	2.011E-04	1.775E-04	1.56E-04	6.400E-04
Visibility (km)	211.2	211.2	211.2	211.2
Visual Range (km)	11	8	22	5
Minimums (ft)	5100	1000	2000	2100
Landing Time (KNOT)	603	1524	1198	1456

Münsterlingen, Germany

Summer 1978

Altitude (m) AGL	Total Volume Scattering Coefficient (m <sup>-1</sup> )			
	(.47)	(.47)		
400	6.700E-05			
450	1.183E-05			
500	5.000E-05			
550	6.01E-05			
600	1.154E-05			
650	6.671E-05			
700	6.400E-05	9.202E-05		
750	7.154E-05	9.645E-05		
800	8.172E-05	9.100E-05		
850	1.154E-05	9.000E-05		
900	6.671E-05	8.000E-05		
950	6.662E-05	8.072E-05		
1000	6.621E-05	1.017E-04		
90	1.610E-05	9.052E-05		
80	1.100E-05	9.117E-05		
Visibility (km)	211.2	211.2		
Visual Range (km)	41	11		
Minimums (ft)	40100	10000		
Landing Time (KNOT)	1070	1630		

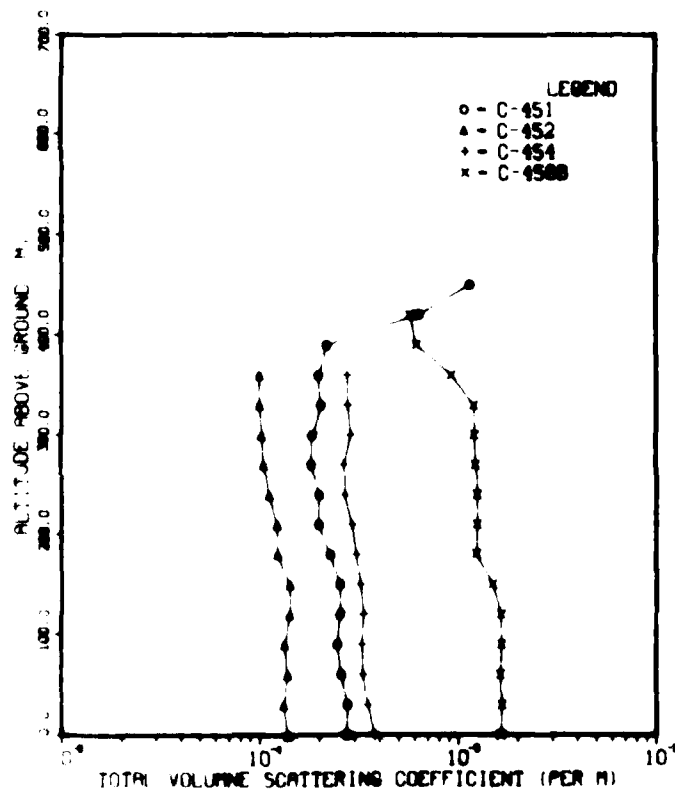
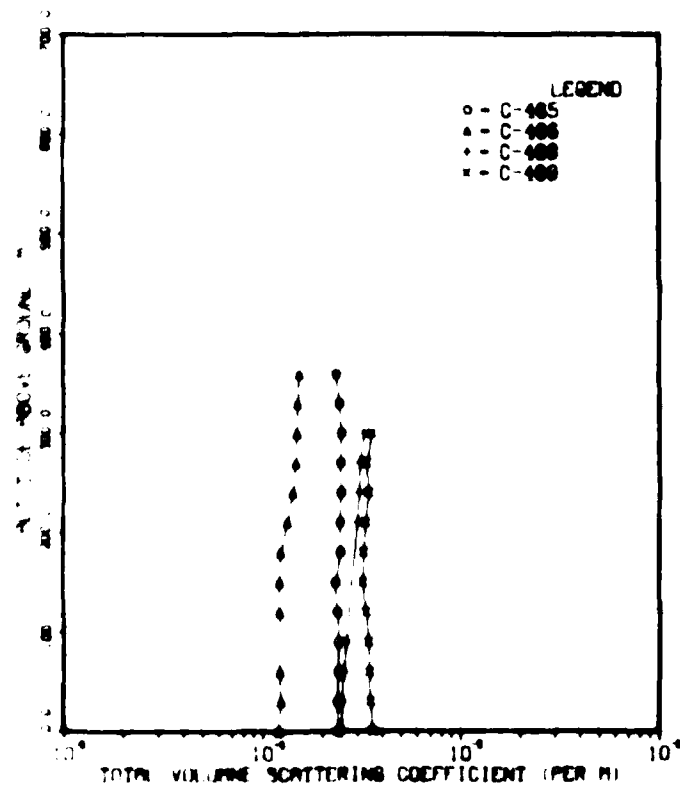


Fig 4-1  
APPROACH PROFILES - GRAPHICAL

Wunstorf, Germany  
Winter, 1978



Wunstorf, Germany  
Summer, 1978

Table 4.3.

## APPROACH PROFILES - TABULAR

Wunstorf, Germany

Winter 1978

Altitude (m) AGL	Total Volume Scattering Coefficient (m <sup>-1</sup> )			
	(.45)	(.452)	(.454)	(.456)
450	1.130E-01			
420	6.700E-04			5.670E-04
390	2.150E-04			6.000E-04
360	1.900E-04	9.097E-04	2.700E-04	9.132E-04
330	2.011E-04	9.004E-04	2.743E-04	1.192E-03
300	1.811E-04	1.020E-04	1.050E-04	1.210E-03
270	2.515E-04	6.00E-04	1.000E-04	1.470E-03
240	2.527E-04	1.007E-04	1.160E-04	1.670E-03
210	2.651E-04	1.20E-04	1.200E-04	1.650E-03
180	2.727E-04	1.300E-04	1.300E-04	1.640E-03
150	2.750E-04	1.300E-04	1.401E-04	1.653E-03
120	2.730E-04	1.300E-04	1.703E-04	1.627E-03
Visibility (km)	2.1	2.1	2.1	2.1
Visual Range (km)	11	21	8	2
Barometric (hPa)	4100	600	4120	1000
Landing Time (GMT)	445	1608	414	1617

Wunstorf, Germany

Summer 1978

Altitude (m) AGL	Total Volume Scattering Coefficient (m <sup>-1</sup> )			
	(.45)	(.456)	(.458)	(.460)
450	2.300E-04	5.67E-04		
420	2.000E-04	5.02E-04		
390	2.500E-04	6.00E-04	1.200E-04	1.555E-04
360	2.000E-04	4.70E-04	1.100E-04	1.302E-04
330	2.000E-04	4.17E-04	1.010E-04	1.260E-04
300	2.70E-04	1.10E-04	1.22E-04	1.110E-04
270	2.000E-04	2.50E-04	1.90E-04	1.570E-04
240	2.000E-04	2.20E-04	2.300E-04	1.240E-04
210	2.000E-04	2.21E-04	2.700E-04	1.100E-04
180	2.00E-04	2.20E-04	2.600E-04	1.000E-04
150	2.000E-04	2.10E-04	2.500E-04	1.000E-04
120	2.001E-04	2.45E-04	2.570E-04	1.100E-04
90	2.00E-04	2.00E-04	2.570E-04	1.001E-04
Visibility (km)	2.1	2.1	2.1	2.1
Visual Range (km)	12	13	12	8
Barometric (hPa)	2150	2070	2120	2000
Landing Time (GMT)	16	161	1114	1009

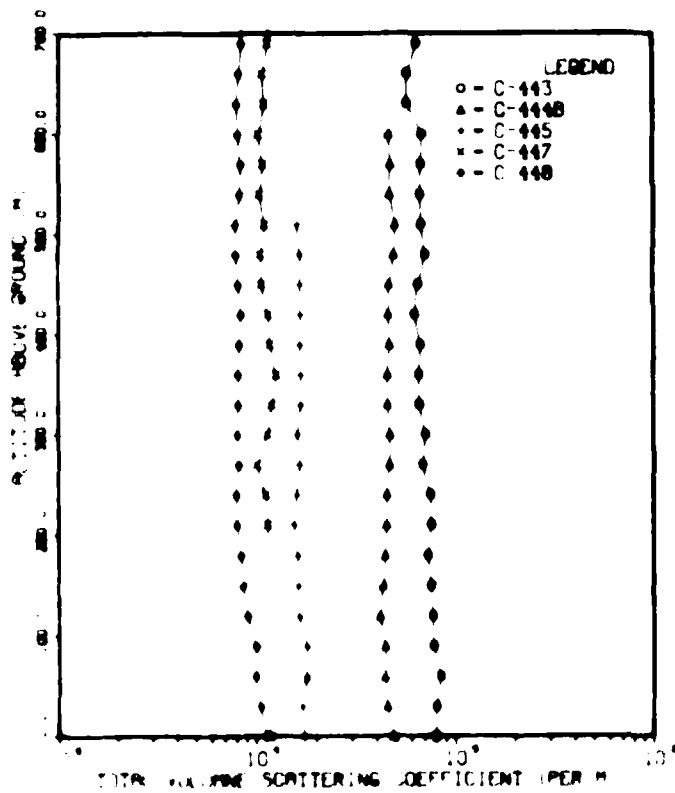
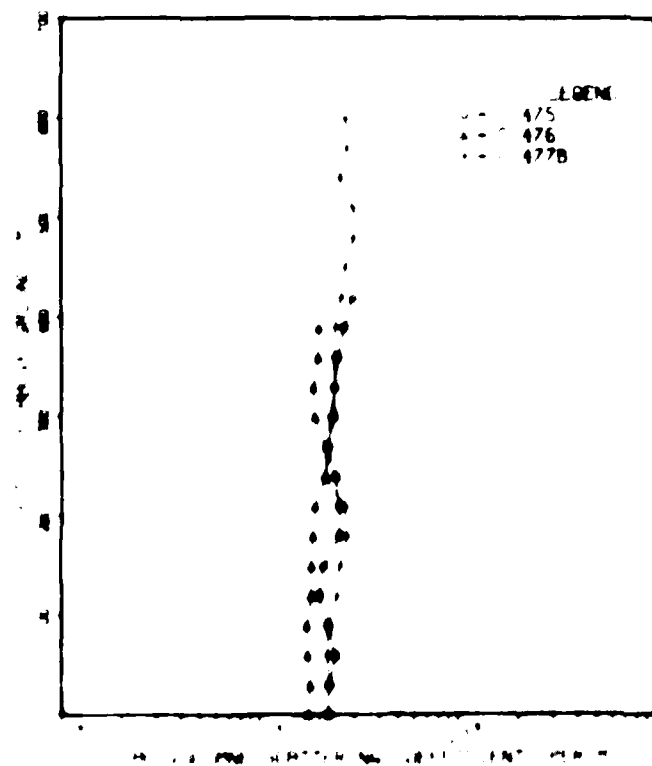


Fig. 44  
APPROACH PROFILES - GRAPHICAL

Widenedhall, England  
Winter 1978



Widenedhall, England  
Summer 1979

**Winter 1978**

January 1978

Altitude	0	100	200
000			100.00
100			100.00
200			100.00
300			100.00
400			100.00
500			100.00
600			100.00
700	100.00		100.00
800	100.00	100.00	100.00
900	100.00	100.00	100.00
1000	100.00	100.00	100.00
1100	100.00	100.00	100.00
1200	100.00	100.00	100.00
1300	100.00	100.00	100.00
1400	100.00	100.00	100.00
1500	100.00	100.00	100.00
1600	100.00	100.00	100.00
1700	100.00	100.00	100.00
1800	100.00	100.00	100.00
1900	100.00	100.00	100.00
2000	100.00	100.00	100.00
2100	100.00	100.00	100.00
2200	100.00	100.00	100.00
2300	100.00	100.00	100.00
2400	100.00	100.00	100.00
2500	100.00	100.00	100.00
2600	100.00	100.00	100.00
2700	100.00	100.00	100.00
2800	100.00	100.00	100.00
2900	100.00	100.00	100.00
3000	100.00	100.00	100.00
3100	100.00	100.00	100.00
3200	100.00	100.00	100.00
3300	100.00	100.00	100.00
3400	100.00	100.00	100.00
3500	100.00	100.00	100.00
3600	100.00	100.00	100.00
3700	100.00	100.00	100.00
3800	100.00	100.00	100.00
3900	100.00	100.00	100.00
4000	100.00	100.00	100.00
4100	100.00	100.00	100.00
4200	100.00	100.00	100.00
4300	100.00	100.00	100.00
4400	100.00	100.00	100.00
4500	100.00	100.00	100.00
4600	100.00	100.00	100.00
4700	100.00	100.00	100.00
4800	100.00	100.00	100.00
4900	100.00	100.00	100.00
5000	100.00	100.00	100.00
5100	100.00	100.00	100.00
5200	100.00	100.00	100.00
5300	100.00	100.00	100.00
5400	100.00	100.00	100.00
5500	100.00	100.00	100.00
5600	100.00	100.00	100.00
5700	100.00	100.00	100.00
5800	100.00	100.00	100.00
5900	100.00	100.00	100.00
6000	100.00	100.00	100.00
6100	100.00	100.00	100.00
6200	100.00	100.00	100.00
6300	100.00	100.00	100.00
6400	100.00	100.00	100.00
6500	100.00	100.00	100.00
6600	100.00	100.00	100.00
6700	100.00	100.00	100.00
6800	100.00	100.00	100.00
6900	100.00	100.00	100.00
7000	100.00	100.00	100.00
7100	100.00	100.00	100.00
7200	100.00	100.00	100.00
7300	100.00	100.00	100.00
7400	100.00	100.00	100.00
7500	100.00	100.00	100.00
7600	100.00	100.00	100.00
7700	100.00	100.00	100.00
7800	100.00	100.00	100.00
7900	100.00	100.00	100.00
8000	100.00	100.00	100.00
8100	100.00	100.00	100.00
8200	100.00	100.00	100.00
8300	100.00	100.00	100.00
8400	100.00	100.00	100.00
8500	100.00	100.00	100.00
8600	100.00	100.00	100.00
8700	100.00	100.00	100.00
8800	100.00	100.00	100.00
8900	100.00	100.00	100.00
9000	100.00	100.00	100.00
9100	100.00	100.00	100.00
9200	100.00	100.00	100.00
9300	100.00	100.00	100.00
9400	100.00	100.00	100.00
9500	100.00	100.00	100.00
9600	100.00	100.00	100.00
9700	100.00	100.00	100.00
9800	100.00	100.00	100.00
9900	100.00	100.00	100.00
10000	100.00	100.00	100.00



## 5. DATA DISCUSSION

As noted in the introductory remarks of section 1, the accurate specification of the atmospheric volume scattering characteristics at very low altitudes can be critical to the determination of slant path contrast transmittances through this near surface regime. It is of major importance for one to know, or be able to reliably deduce, the occurrence of major variations in the vertical structure of the atmospheric aerosol. The flight data represented in the earlier referenced reports (Johnson and Gordon, 1980 etc.) have provided extensive samples of these variations and thus have served as the case studies required for developing reasonable modelling representations. A preliminary discussion of a proposed modelling technique was originally discussed in Johnson *et al.* (1979) has been amplified upon in Johnson and Hering (1981) and is described further in Hering (1981).

Since the profile data upon which the Hering model was developed terminated at 500 to 1000 ft (150-300m) above the ground, the confidence with which one could specify the low level scattering properties from these data was somewhat compromised. The data presented in section 4 of this current report specifically address the resolution of the uncertainty in this specification. They support the contention that the most cases, including measurements of atmospheric optical scattering coefficient made within the 500-1000 ft AGL altitude regime may be reliably extrapolated down to the surface with only marginal risk of significant errors in the context of small model perturbations. With the nine winter and summer profiles (as indicated in 4.1) only three, the winter measurements of Malmgren, show marked increases in low level values. There is additionally one minor increase at the surface indicated by flight 434 (winter Sigonella), but it is not so deep an extensive shift as is indicated in Malmgren measurements. The specific conditions underlying these near surface low altitude phenomena have not yet been identified.

One other major aspect of this admittedly limited data sample is the relatively small but bear additional modeling implications, the small spread in the sea surface scattering coefficient magnitudes. With the singular exception of the Sigonella data, the winter measurements represent a considerably broader variation in scattering coefficient values than do the summer measurements. This is a particular feature of the Malmgren data, and is not necessarily a result of measurement upon with greater confidence, as the number of data sample increases. As indicated in 4.1, for each flight, these data represent a few measurements in the most part, and thus do not necessarily reflect well mixed, vertically stable conditions. They do, however, reflect the near surface conditions prevailing with early morning or evening heavy fog scattering.

### 5.1. Summary

Two vertical profiles of the photopic atmospheric volume scattering coefficient representing both

winter and summer conditions at four separate European aerodromes have been presented for evaluation. The basic question to be addressed is whether or not the scattering coefficient profile remains reasonably constant as one approaches the surface from an altitude of several hundred meters, and if not, what is the character of the vertical structure. These data indicate that in twenty six out of twenty nine instances, the profile is essentially constant in value and thus the modelling approach proposed by Hering (1981) is in fact an appropriate procedure. The identification of the conditions resulting in the three profiles showing abrupt near surface increases in scattering should be addressed as a separate problem, where the larger four season data base has been developed.

## 6. ACKNOWLEDGEMENTS

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## APPENDIX B

### VISIBILITY LABORATORY CONTRACTS AND RELATED PUBLICATIONS

#### Previous Related Contracts:

F19628-73-C-0013, F19628-76-C-0004

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